Calculating Latent Heat Fluxes Over the Labrador Sea
Using SSM/I Data

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LONG-TERM GOAL

To develop a methodology for remotely measuring the spatial and temporal variability of the atmospheric surface latent and sensible heat fluxes over the Labrador Sea using passive microwave imagery (SSM/I).

OBJECTIVES

(1) To test existing algorithms for calculating integrated water vapor (IWV) and surface wind speed and compare these calculations to shipboard measurements made from the Knorr during the 1997 experiment. Calculate surface flux fields over the Labrador Sea.

(2) Develop algorithms optimized for use during cold air outbreak conditions in the Labrador Sea using the 1997 Knorr data and compare SSM/I-derived estimates of fluxes made at the position of the Knorr with values of NCEP and ECMWF model fluxes.

APPROACH

It has been well proven that one can estimate atmospheric integrated water vapor (IWV) and surface wind speed using SSM/I data. Algorithms have been developed by using oceanic sounding data sets and buoys in conjunction with radiative transfer models and multiple regression techniques to relate brightness temperatures (Tb's) from different SSM/I channels and IWV and wind speed at 19.5 m height. The SSM/I instrument on the DMSP series of satellites operates at four frequencies (19, 22, 37 and 85 GHz), and at horizontal (H) and vertical (V) polarizations at 19, 37 and 85 GHz and at V polarization at 22 GHz. Spatial resolution is nominally 50 km at 19, 22 and 37 GHz and 25 km at 85 GHz.

Using over-the-ocean radiosondes Liu (1986) showed that IWV was highly correlated with surface mixing ratio (q_a) on a monthly averaged basis. Subsequently, Hsu and Blanchard (1988) showed this relationship held for individual soundings. Previous studies have shown that latent heat fluxes can be estimated from quantities (IWV and wind speed) that can be estimated from SSM/I data (Claud et al, 1992; Clayson and Curry, 1996).

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Claud et al (1992) developed an empirical relationship between IWV, derived from SSM/I brightness temperatures, an independent estimate of T_{sfc}, and (q_s-q_a), where q_s is the saturation mixing ratio at the ocean surface temperature T_{sfc}, q_a is the mixing ratio of the air near the ocean surface. Having (q_s-q_a) and wind speed, u, allows us to calculate a value of the latent heat flux, LHF, using the bulk method:

$$LHF = L_v*\rho*C_E*u*(q_s-q_a), \quad (\text{in } W/m^2), \text{ where}$$

ρ is the air temperature, C_E is the water vapor transfer coefficient, and L_v is latent heat of evaporation.

An estimate of the sensible heat flux, SHF, can also be made from SSM/I data using the fact that the air temperature T_a is related to the value of IWV (Jourdan and Gautier, 1995).

Using the bulk flux method the SHF can then be calculated from:

$$SHF = \rho*C_p*C_H*u*(T_{sfc}-T_a), \quad (\text{in } W/m^2), \text{ where}$$

C_p is the specific heat, and C_H is the heat transfer coefficient.

WORK COMPLETED

In FY 98 modifications were made to existing SSM/I algorithms for estimating integrated water vapor (IWV), surface wind speed, u, and (q_s-q_a) using meteorological data collected by the Knorr during the 1997 field program. From the NSIDC SSM/I CDROMs, I extracted the SSM/I brightness temperature fields for the area 51^0 N - 67^0 N and 67^0 W - 43^0 W, containing the Labrador Sea.

In FY 99 using these algorithms and the bulk form of the flux equations above, I then calculated both the spatial and temporal variations of the LHF and SHF fields for this area. I then found the SSM/I cell containing the Knorr during its cruise in the Labrador Sea during 6 February - 13 March, 1997 and estimated the fluxes for that cell from the SSM/I data. I also obtained the fluxes from both the NCEP and ECMWF model output for the location of the Knorr during this time period and compared the values from the SSM/I data and the model values. The ECMFW and NCEP fields were kindly supplied by Dr. Ian Renfrew.

RESULTS

In developing the following algorithms I followed the functional form suggested by Claud et al (1992) for both the IWV and wind algorithm. The Claud et al (1992) wind algorithm was based on that developed by Goodberlet et al (1989). The results for the regression analyses for the Labrador Sea data are as follows:

IWV = - 16.4415 + 0.9302*T22v + 0.8563*T19v,   (r=0.94)

u = 193.557 + .3777*T19v - .0276*T22v - 1.7815*T37v + .8195*T37h,
(r=.766).

I followed the approach of Miller and Katsaros (1992), except using only a linear dependence on T_s, in deriving a relationship between IWV, T_s and (q_s-q_a) giving:

$$(q_s\text{-}q_a) \text{ pred} = 3.213 - .2605*IWV + .33104*T_s, \quad (r=.925)$$

Also, following the approach of Jourdan and Gautier (1995) and using the daily averaged values of T_a from the Knorr and IWV from the radiosondes I obtained the following relationship between T_a and IWV:

$$T_a = -25.27*exp(-.305*IWV) + 2.0.$$

The daily average values of latent and sensible heat flux fields calculated using SSM/I brightnesss temperature fields for the Labrador Sea show spatial variations that are in qualitative agreement with NCEP fields.

The correlation coefficient between latent heat fluxes obtained from the in situ measurements on the Knorr and those obtained from the SSM/I algorithm was $r = 0.907$. The correlation coefficient between the Knorr's sensible heat fluxes and those from the SSM/I algorithm was $r = 0.88$. The following table shows a comparison of the values of the SSM/I fluxes and the ECMWF and NCEP fluxes at the location of the Knorr averaged over the whole cruise.

	SSM/I (predicted)	ECMWF	NCEP
LH flux, W/m^2	153.0 +/- 54.4	143.4 +/- 67.9	164.4 +/- 79.4
SH flux, W/m^2	216.9 +/- 111.2	200.1 +/- 116.2	268.5 +/- 157.5

As can be seen, the predicted fluxes are very much in line with the ECMWF flux fields, but both are considerably smaller than the NCEP fluxes, especially the sensible heat flux. Renfrew et al. (1999) discuss the reasons for the large values of the NCEP fluxes. Likewise, comparisons of the daily average SSM/I-derived fluxes and daily average ECMWF fluxes at the Knorr are remarkably good.

IMPACT/APPLICATION

If this method of remotely estimating surface turbulent sensible and latent heat flux fields proves robust it would provide a method for supplying data for initializing oceanographic numerical models, and for the analysis/interpretation of oceanographic measurements. Having these higher resolution (~50 km) flux fields is critical for studying the scales of oceanographic processes important for deep convection in the Labrador Sea.

TRANSITIONS

The above technique can be applied to other geographic areas for similar wintertime cold air outbreak conditions.

RELATED PROJECTS

The work here is related to that being carried out by Renfrew et al (1999) where they have compared heat flux measurements made by the Knorr and fluxes obtained from the NCEP reanalyses and the ECMWF operational forecast products.

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